The Plus Side

Promoting Sustainable Carbon Sequestration in Tropical Forests

Union of Concerned Scientists

Citizens and Scientists for Environmental Solutions

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NOVEMBER 2010

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The UCS Tropical Forest and Climate Initiative analyzes and promotes ways to cut global warming pollution by reducing tropical deforestation.

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Designed by:
DG Communications, Acton, MA | *www.NonprofitDesign.com*

Cover photos:
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Printed on recycled paper.

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Acknowledgments

This report was made possible through the generous support of ClimateWorks Foundation and The David and Lucile Packard Foundation.

The authors are indebted to Eduardo Arellano of Universidad Catolica in Santiago, Chile, Amy Daniels of the U.S. Forest Service, Karen Holl of the University of California–Santa Cruz, and Clinton Jenkins of the University of Maryland, who each provided expert review of this report.

The insights of Doug Boucher and Sarah Roquemore at the Union of Concerned Scientists (UCS) helped make this report more relevant and thorough. Estrellita Fitzhugh, Noel Gurwick, Ben Larson, Jeremy Martin, and Calen May-Tobin at UCS, Lisa Moore at Environmental Defense Fund, and independent consultant Earl Saxon also helped us think critically about broadening the report.

Thank you to all.

CHAPTER 1
Introduction

Deforestation in tropical countries accounts for about 15 percent of global warming pollution. Tropical forests are a net source of carbon emissions because vast areas are being cleared for agricultural expansion. Because the remaining forests grow slowly, they sequester—that is, absorb from the atmosphere—only small amounts of carbon each year.

To help mitigate the worst effects of climate change, nations should reduce net global warming emissions from tropical forests 50 percent by 2020, and bring them to zero by 2030 (Elias and Boucher 2010). However, a rapid reduction in deforestation and forest degradation will not be enough to achieve those goals. These nations must also scale up activities that increase carbon sequestration in tropical forests.

Participants in the United Nation's Framework Convention on Climate Change first introduced the idea of reducing emissions from deforestation—known as RED—at the 13th Conference of the Parties in 2007. Then, at the fifteenth conference, in 2009, participants agreed to expand this idea to include reducing degradation as well as deforestation of tropical forests, conserving their carbon stocks, managing these forests sustainably, and increasing the rate at which they sequester carbon. The mechanism to pay developing nations to pursue these activities is known as REDD+.

The first two of these activities—reducing deforestation and forest degradation—are the fastest and most cost-effective way to reduce carbon dioxide emissions from tropical forests (Verchot et al. 2010; Angelsen et al. 2009). If acted on quickly, those two activities will also have the biggest impact on climate change of all REDD+ activities (Niles et al. 2002). The third activity—conserving carbon stocks—is also a critical part of the REDD+ mechanism.

However, the fourth and fifth REDD+ activities—managing tropical forests sustainably, and boosting their ability to sequester carbon—are key to converting these forests into a net carbon sink. That's because while natural regrowth is creating secondary forests in the tropics (Wright 2010), a REDD+ mechanism could spur developing countries to increase the amount of land devoted to such forests, and to accelerate their growth rates—and thus the rates at which they sequester carbon.

A forest restoration research site in Costa Rica.

Calen May-Tobin

Activities to enhance the rate at which tropical forests sequester carbon are especially important in the many large developing countries that have moved past a phase of forest loss and are now expanding forest cover. As of 2000, China, India, Chile, Cote d'Ivoire, and Vietnam are reforesting on the largest scale (Table 1, p. 2).

If properly crafted, REDD+ policies could shift the world's tropical forests from being net emitters of carbon dioxide to becoming a major net sink. However, these policies should provide financial incentives only for forestry activities that actually tackle climate change by either reducing emissions or increasing sequestration. For example, a REDD+ system should not pay

TABLE 1. The Potential of Developing Countries to Participate in a REDD+ System

Country	Forest Cover in 1990 (1,000 hectares)	Forest Cover in 2005 (1,000 hectares)	Percent Change
Countries with *high rates* of tropical deforestation: REDD+ activities will focus mainly on reducing emissions from deforestation and degradation			
Brazil	520,027	477,698	-8%
Indonesia	116,567	88,495	-24%
Venezuela	52,026	47,713	-8%
Zambia	49,124	42,452	-14%
Papua New Guinea	31,523	29,437	-7%
Paraguay	21,157	18,475	-13%
Nigeria	17,234	11,098	-35%
Honduras	7,385	4,648	-37%
Countries with *low rates* of tropical deforestation: REDD+ activities will focus on conserving forest carbon and increasing sequestration			
Democratic Republic of the Congo	140,531	133,610	-5%
Peru	70,156	68,742	-2%
Colombia	61,439	60,728	-1%
Congo	22,726	22,471	-1%
Gabon	21,927	21,775	-1%
South Africa	9,203	9,203	0%
Kenya	3,708	3,522	-5%
Belize	1,653	1,653	0%
Countries with *expanding areas* of tropical forests: REDD+ activities will focus on increasing carbon stocks and sequestration			
China	157,141	197,290	25%
India	63,939	67,701	6%
Chile	15,263	16,121	6%
Cote d'Ivoire	10,222	10,405	2%
Vietnam	9,363	12,931	38%
Uruguay	905	1,506	66%
Gambia	442	471	7%
St. Vincent and the Grenadines	9	11	22%

Source: Food and Agriculture Organization 2005.

Note: Each country self-reports these data.

Second growth (foreground) and the Palo de Mayo forest (background), southeastern Nicaragua

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developing nations for harvesting timber from naturally forested areas, or for converting diverse and carbon-rich ecosystems into tree plantations.

A REDD+ mechanism should also aim to promote biodiversity, ecosystem services, and the well-being of local communities while reducing net carbon emissions. To ensure that REDD+ reduces net global warming emissions while promoting sustainable development, policy makers will need to ensure effective accounting of those emissions, and create environmental and social criteria for REDD+ activities.

This report provides background on how forestry practices can shift the role of tropical forests with respect to climate change—from being sources of heat-trapping emissions to sequestering carbon and reducing the impact of climate change, among other benefits. While the only way to fully address climate change is reducing the use of fossil fuels, incorporating the role of appropriate sustainable forest activities in crafting policies will help achieve the goal of zero net emissions from tropical forests. This report outlines various techniques for managing tropical forests sustainably while enhancing their ability to sequester carbon. It also shows how to ensure that activities are "additional"—that is, beyond business as usual—and outlines the global potential of tropical forests to help mitigate climate change. Finally, the report proposes international and national policies to ensure that REDD+ activities achieve their core goal while adhering to strict environmental and social standards.

Degraded land in Costa Rica where heavy grass and fern cover is preventing natural forest regeneration.

Calen May-Tobin

CHAPTER 2

The Fundamentals of Forest Management

A REDD+ system can change the activities owners and managers of tropical forests choose to pursue based on the income they can generate. That is, under a REDD+ system, the carbon benefits of a tropical forest will become another financial asset along with timber and other products.

However, the carbon benefits of conserving tropical forests and enhancing their ability to sequester carbon will vary across regions with different land-use histories. Protecting standing forests will prevent carbon emissions that would have occurred if the forests had been converted to agricultural or other land uses, or if they had degraded through poorly planned, unsustainable timber harvesting. Reforestation and restoration of already cleared or degraded landscapes can increase carbon stocks. And managers of forests already used to produce timber can use specific techniques to reduce logging-related emissions and boost carbon sequestration (Figure 1, Table 2).

A view across mountains in Costa Rica shows a variety of forest uses and histories of use.

Calen May-Tobin

FIGURE 1. Forestry Practices to Reduce Carbon Emissions and Increase Sequestration

Objective	Increased Sequestration		Reduced Emissions from Forestry		
Practice	**Forest Management Plans**	**Adaptive Management**	**Reduced-Impact Logging: Site-Specific Timber Operations**	**Changes in Harvesting Density**	**Soil Improvement**
Action	• Increase rotation length • Improve regeneration • Use enrichment plantings • Plant tree island/clusters • Use secondary forests rather than primary forests for production	• Select best species for the site • Continually assess and apply lessons learned • Apply appropriate principles at different sites	• Training of harvesters and planning • Precision & smaller machinery • Working during appropriate weather conditions • Build roads and skid trails properly, primarily to avoid erosion • Cut vines to prevent inadvertent damage to neighboring trees	• Mark timber so only appropriate trees are removed • Implement diameter-limit cuttings to leave growing stock for the next generation	• Plant nitrogen-fixing species to improve soil fertility • Use biochar or other low-carbon-footprint fertility treatment • Protect soil fertility

TABLE 2. Various Benefits of Forest Management Activities

Forest Management Activity				
Protecting primary forest	Natural regeneration	Enrichment planting	Community management of secondary forest	Extracting timber products from secondary forest
Effects on Carbon Emissions and Sequestration				
Reduces carbon emissions	Sequesters carbon	Sequesters carbon	May sequester carbon	May sequester carbon

– → Increasing level of silvicultural intensity → +

+ ← Biodiversity benefits ← –

CHAPTER 3

Using Reforestation and Restoration to Mitigate Climate Change

Promoting Natural Regeneration

Developing countries participating in a REDD+ program should aim first to protect relatively undisturbed tropical forests from deforestation and degradation. That's because efforts to intensively manage natural, healthy forests, such as by harvesting, will likely produce net global warming emissions. Thus, they should not qualify for payment under a REDD+ system (Liao et al. 2010).

In degraded areas where long-term land use and changes in species have significantly slowed or prevented natural regrowth, landholders may need to pursue more intensive management to restore the forest and increase the rate at which it sequesters carbon.

However, on degraded land and land already converted to other uses, countries can pursue forest management activities that sequester carbon. Such efforts should qualify for REDD+ payments while also yielding essential or financially valuable forest products.

Managers of degraded and secondary forests can promote natural regeneration by preventing fires, conserving soil, and protecting key tree and animal species, as many of the latter help disburse tree seeds (Carilla and Grau 2010; Hooper, Legendre, and Condit 2005; International Tropical Timber Organization 2002).

Tree Planting

In degraded areas where long-term land use and changes in species have significantly slowed or prevented natural regrowth, landholders may need to pursue more intensive management to restore the forest and increase the rate at which it sequesters carbon. The goal is to mimic the structure and species composition of a naturally regenerating forest by avoiding permanent degradation, encouraging propagation of desired species, and promoting quicker restoration (Ashton et al. 2001).

Landholders can use several protection and planting techniques to promote forests along these restoration pathways, mixing and matching them as appropriate:

Protecting forests from humans and herbivores. Protecting degraded land, such as by using fencing to prevent grazing, can allow regrowth to develop naturally.

Reducing fire risk. Land managers can promote forest regeneration by clearing species that provide fuel for fires, such as ferns and grasses, which also compete with tree seedlings for light. Fire prevention is important in areas where tree seedlings cannot survive fires, as it allows them to become larger and more fire-resistant.

Enrichment planting. In this approach, land managers add species missing from the forest ecosystem, such as dominant and understory trees and shrubs, without disturbing the structure of the existing forest.

Mimicking old-field succession. Ecologists have long studied the natural changes that occur as old agricultural fields convert back to native forests. Managers of severely degraded and compacted land can jump-start this natural process by planting native pioneer species (those that appear first as an old field becomes a forest).

Creating mixed-species plantations. Managers of land with few trees—which therefore has few seeds for regenerating natural forests—may have to plant a mix of native species to spur the land to revert to forest.

These techniques can do more than encourage the growth of healthy forests. Enrichment planting, for example, can also restore degraded soils. By preventing forests from degrading further, enrichment planting may also stop people from converting them to other land uses that produce even higher net carbon emissions (Montagnini, Eibl, and Fernández 2006).

Enrichment planting is more costly than some lower-intensity activities, like fire prevention. However, REDD+ payments can enable land managers to recover some of the costs of boosting carbon sequestration on highly degraded sites where natural regeneration would have taken a long time. Land managers can also plant fruit trees and high-value timber species on these degraded sites to reap other income during the restoration process.

Land managers can also cut their costs by using a mixture of practices, and limiting the area where expensive techniques are used. For example, planting only in "tree island" clusters will reduce costs, while still providing seed sources for the remaining area. Because proximity to seed sources affects the ability of a largely deforested area to regenerate naturally, planting islands of mixed tree species can provide seeds for dispersal across the area (Hooper, Legendre, and Condit 2005). It is important to remember that while planting fewer trees in islands is less expensive, it also often results in slightly lower rates of regrowth (Cole et al. 2010; Holl et al. 2010).

Directly planting seeds—especially of species with large seeds—can also be 10 to 30 times cheaper than planting nursery-grown seedlings on degraded lands (Cole et al. 2010). Additionally, relatively inexpensive activities, such as preventing fires, can be used on some patches of land while costlier activities, such as planting trees, can be pursued on others (Hooper, Legendre, and Condit 2005).

Critically assessing the need for restoration and reforestation techniques—and determining which are most appropriate—is important for both reducing costs and ensuring the environmental integrity of these activities (Holl and Aide 2010).

Managed Secondary Forests

Where more intensive management than the restoration pathways described above is necessary, large-scale tree planting can promote secondary growth of tropical forests (Carnevale and Montagnini 2002) and may be a cost-effective method for increasing carbon sequestration in deforested areas (Hooper, Legendre, and Condit 2005; Sampson and Sedjo 1997). Plantations need not be large monocultures used to produce timber; landholders can plant diverse and complex forests.

The history of Puerto Rican forests shows how plantations can promote reforestation. By the mid-nineteenth century, only 10 percent of Puerto Rico remained forested (Grau et al. 2003). However, through large-scale planting many of the country's forest ecosystems have since recovered to 40 percent forest cover, providing a wealth of information on how secondary forests can be established. This experience shows that regeneration of deforested areas that have not been degraded can produce mature secondary forests in just 40 years. In some cases, using planting techniques can

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Seedlings awaiting planting at a forest restoration research site in Costa Rica.

create secondary forests whose species composition is closer to that of primary forests more quickly than allowing forests to regenerate without intervention (e.g., Aide et al. 2000; Parrotta 1992).

The structural and biological complexity of mixed-species plantations can serve multiple purposes while maintaining environmental integrity. For example, secondary forests can be used for fuelwood, food, and other non-timber forest products while restoring ecosystems. The Puerto Rican forests have become critical for providing both timber and environmental services such as carbon sequestration (Guariguata and Ostertag 2001).

"Experience during the past several decades indicates that local communities are prepared to accept responsibility for sustainable forest management in exchange for socioeconomic development and forest-use benefits."

(International Tropical Timber Organization 2002)

Currently, small landholders create mixed-species plantations to restore degraded areas more often than commercial timber producers (Nichols, Bristow, and Vanclay 2006). However, modest payments that compensate all landholders for the higher costs of managing these plantations can help promote them over monocultures.

Adaptive Management

Adaptive management is an iterative process used by foresters to compare results against goals. This is especially important in the diverse forest of the tropics since techniques will have to be tweaked from location to location. Using adaptive management, land managers can constantly adjust their approach as they receive data on how well a forest is reaching goals, such as faster carbon sequestration and community development.

Adaptive management requires approaching forestry with humility, and without assuming that recommendations for one landscape and community are appropriate for all others. Through constant learning, foresters can modify their activities to improve carbon sequestration rates across different types of forests and landscapes, based on the needs of different ecosystems. This is especially important for restoration and reforestation activities in tropical countries, where success can vary widely across the diverse tropical landscape (Marin-Spiotta et al. 2008).

Although adaptive management is critical in tropical countries, it is not widely practiced. To do so would require building capacity to train land managers and monitor results (McGinley and Finegan 2003; International Tropical Timber Organization 2002). However, small studies have shown that workshops with forestry experts and other stakeholders can spur tropical nations to incorporate adaptive management into their forest management plans (e.g., McGinley and Finegan 2003).

The example of indigenous people and local communities is especially important in practicing adaptive management in the tropics. Similar to many traditional ecological practices, which adjust management based on ecosystem feedback, adaptive management also uses monitoring data to influence changes in specific activities (Berkes, Colding, and Folke 2000).

Community Forestry

Deliberately planned community forestry may be one of the most useful tools for pursuing REDD+ while tapping the knowledge of local residents. Community forestry has three basic features (Charnley and Poe 2007):

- Government gives communities formal responsibility for managing forests
- Communities take responsibility for practicing ecologically sustainable forestry
- Local social and economic benefits are central goals of that approach

Community forestry has many benefits, including integrating local knowledge and goals into efforts to conserve carbon and sequester more of it, and implementing sound principles of forest management. Community forestry may also aim to spur local land ownership, but it can occur under various forms of land tenure, including privately owned land, government-owned land, forests held as common capital, and land owned or controlled by indigenous people. Regardless of the ownership arrangement, land tenure must be clearly defined and legally enforceable to enable forestry practices to qualify for payments under REDD+.

Community forestry also aims to promote local economic development while protecting forests. For example, in Mexico, governance structures promoting such forestry have enabled communities to sell timber and non-timber products while also protecting forests and local ecology (Bray, Antinori, and Torres-Rojo 2006). Other countries such as Bolivia, India, Nepal,

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A staff member from the Sustainable Harvest Initiative takes notes on the condition of a forest restoration site in Honduras. Adaptive management requires learning from previous work and, if necessary, adjusting next steps to reach the desired restoration goals.

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A seedling planted on a forest restoration research site in Costa Rica.

and the Philippines have also successfully implemented community forestry (Charnley and Poe 2007). In India, estimates suggest that 8.3 million families are managing 17.5 million hectares through community forestry (World Bank 2006).

REDD+ can promote local sustainable development by providing supplementary payments to communities and families who garner other income, goods, and services from local forests. Sustainable management of forests and economic development should go hand in hand. In a recent study comparing 80 forest commons in 10 tropical countries, Chhatre and Agrawal (2010) found that larger forests and those with highly autonomous local control were more beneficial for both local livelihoods and carbon storage than smaller tracts with less local control.*

Because of these benefits, community forestry can actually be more effective in reducing deforestation than giving forests legal "no-touch" status. By designating different areas for different activities, community forests can provide multiple benefits. For example, both timber removal and reforestation of cattle pastures are occurring simultaneously in a community forest on the Yucatan Peninsula (Ellis and Porter-Bolland 2008).

* Chhatre and Agrawal define forest commons as an area of "forests used jointly by a relatively large number of often heterogeneous users, with defined boundaries for the forest and its user group, and legally enforceable property rights to streams of benefits of the forest" (2010).

CHAPTER 4

Managing Production Forests to Mitigate Climate Change

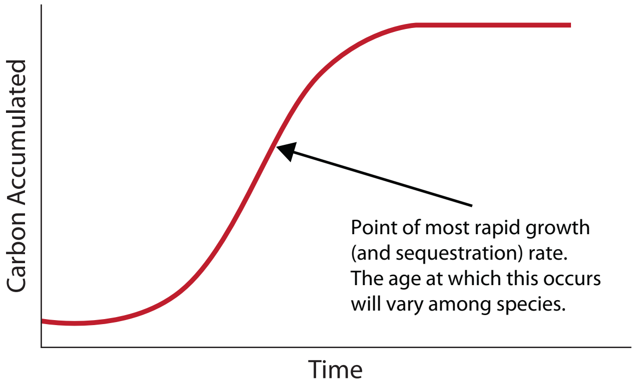
While REDD+ should primarily prevent emissions from deforestation or degradation of natural forests, these policies can also pay countries to increase carbon sequestration in already established secondary forests used for production. Several forestry tools, including reduced-impact logging, longer harvest rotations, and the use of bio-based fertilizers, can improve the growth rate of trees in such forests (Figure 2). Analysts worldwide have recognized the role of these tools in boosting the rate of carbon sequestration in forests used to produce timber (e.g., Sampson and Sedjo 1997).

Curbing Emissions through Reduced-Impact Logging

Foresters can use reduced-impact logging (RIL) to cut global warming emissions from timber-harvesting activities (Putz et al. 2008). RIL practices include modifying harvesting density—that is, the number and size of trees left on a site. Changing harvesting density, such as by leaving trees of certain sizes to increase carbon sequestration in the next rotation, helps integrate logging and forest management. Lower-intensity harvesting—selecting individual trees versus clear-cutting—can also increase the amount of carbon stored on-site (Davis et al. 2009), although the effect of this practice on tropical stands needs more investigation.

Site-specific yarding—in which foresters change log-removal methods depending on topography, avoid

FIGURE 2. Natural Growth Curve of a Tree



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Reduced-impact logging practices include vine cutting. Since a single vine can spread across multiple trees, cutting these prevents the vine from pulling down trees that should remain standing.

harvesting when soils are very wet, and remove timber with draft animals rather than machinery—protects the productivity of forested land and reduces degradation. Other RIL tools include curbing damage to residual trees (those left in the forest) and establishing no-cut zones in areas with steep slopes or close to streams, or in wildlife reservoirs.

While RIL increases carbon emissions and reduces sequestration more than not logging, it can improve ecological conditions while curbing emissions in forests designated for production. In Indonesia, for example, over many decades a RIL plan is expected to reduce disturbance to soil and residual vegetation by 50 percent, and cut costs by 15 percent, compared with conventional logging (Sist, Dykstra, and Fimbel 1998).

While reduced-impact logging increases carbon emissions and reduces sequestration more than not logging, it can improve ecological conditions while curbing emissions in forests designated for production.

A multistoried plantation in Belize features coffee, yellow ginger, and mango.

In the Amazon, RIL experiments show that this practice can help reduce the impact of logging on wildlife (Presley et al. 2008; Wunderle, Henriques, and Willig 2006)—although landholders should avoid logging entirely in habitats for critical species (Felton et al. 2008). In Cameroon, RIL reduced damage to residual trees but was also very costly (Jonkers 2000), while in the Amazon RIL ultimately cost 12 percent less than conventional logging (Holmes et al. 2000).

Given the variability in timber stands, prices, and the ability of developing countries to pursue RIL, an international REDD+ mechanism that provides financial incentives may be essential to make this approach economically feasible. And while landholders must create a new RIL plan for each harvest, policies that define and standardize RIL may help such projects become certified and ultimately broaden participation (Ezzine De Blas and Ruiz Perez 2008).

Increasing the Length of Harvest Rotations

Lengthening rotations—or the intervals at which timber in production forests is cut—also increases the rate of carbon sequestration. Stands cut after 80 years rather than 40 years will have larger carbon stocks in remaining timber, both when cut and as an average over the long run. That is especially important if foresters have been cutting trees at an age when they are sequestering carbon quickly (Figure 2). Landholders usually find it easier to increase rotation length when they are managing large tracts of forest, so this practice may have limited use in locations with small landholders.

Improving Soil Fertility

Managers can further increase carbon sequestration during stand rotation by improving soil fertility and selecting a mix of species best suited for the site. However, the manufacture of many common fertilizers releases large amounts of heat-trapping emissions, so landholders should improve fertility by interplanting trees with nitrogen-fixing species, or by using bio-based fertilizers (see Box 1) (DeBell et al. 1997). The use of fertilizer in tropical forests is also complicated by the fact that the nutrient needs of different sites are variable and often difficult to determine (Tanner, Vitousek, and Cuevas 1998), and the costs of fertilizing sites can be prohibitive.

BOX 1.

Using Biochar to Sequester Carbon

Some scientists have proposed the production of biochar—any carbon-rich by-product of baked organic material—as a way to use forestry waste to sequester carbon (Bruges 2009). To create biochar, producers rely on pyrolysis: they bake leaves and branches from timber harvest, bark from logs, sawdust from mills, and other plant or animal wastes in a low-oxygen environment. Biochar can be produced in a wide range of conditions and scales, including kitchen stoves, each creating a biochar with different chemical characteristics. Normally biochar is used by applying it to the soil or burying it, where it may act as a fertilizer for plants.

The carbon in any plant-based feedstock used for biochar originates as CO_2 in the atmosphere. Most renewable fuel cycles return this carbon to the atmosphere. By creating a stable carbon product and burying it in the soil, in contrast, biochar may effectively sequester carbon from the atmosphere. Studies have shown that soil can sequester the carbon for hundreds and even thousands of years (Sohi et al. 2010).

To earn credit for using biochar to sequester carbon, manufacturers must ensure that the entire production cycle—from growing the plants to transporting the biochar material—is carbon-negative, and that they apply the biochar to appropriate soil types. More research is needed to understand the carbon life cycle of biochar production, as well as how the material interacts with different types of soil over a long period. Biochar production based on that understanding may become a useful tool for sequestering carbon.

Incorporating biochar into the soil in Honduras.

CHAPTER 5

Beyond Business as Usual: Ensuring That Carbon Benefits Are Additional

To receive REDD+ payments for cutting global warming emissions from tropical forests or using them to sequester carbon, developing countries would have to calculate a baseline: the emissions or sequestration that would have occurred under business as usual, or without intervention. Any cuts in emissions or increases in carbon sequestration above the baseline are "additional": that is, they benefit the atmosphere, and so could qualify for payments (Figure 3).

To ensure that sequestration is additional, a REDD+ system should not compensate countries for simply letting existing forests grow as they naturally would. Instead, the system should compensate them for sequestration that occurs beyond the baseline rate because of policies that spur sequestration through any of three approaches:

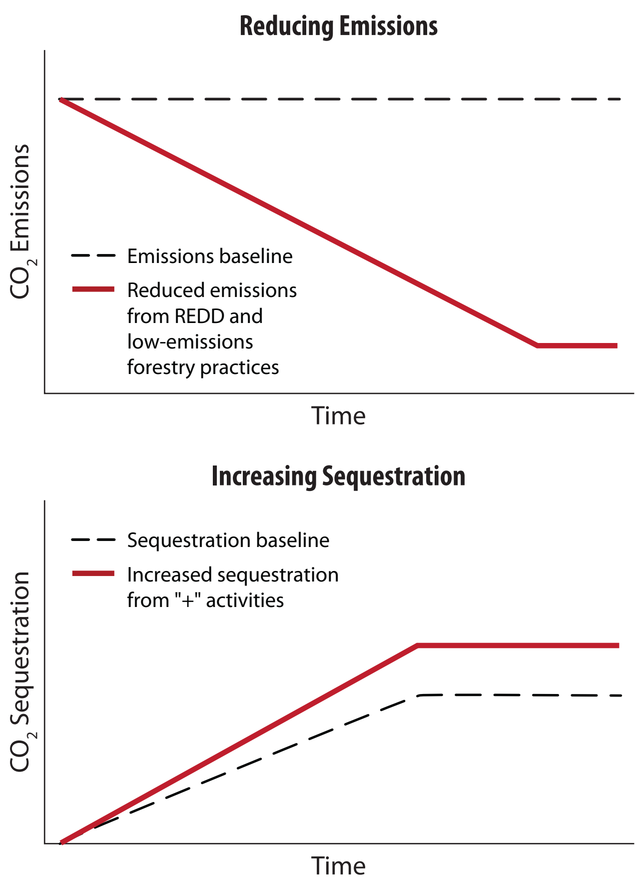
- Faster growth rates in existing forests
- Expanded area of deforested and degraded land that is reforested and restored
- Management changes in forests pre-designated for timber products

To qualify for payments under a REDD+ system, countries must prove that these activities resulted in quantified increases in sequestration rates (Figure 3). Of course, countries could not claim credit for such changes if landholders have already received payment for producing carbon "offsets" (changes that offset the emissions of another entity, such as companies or individuals in developed countries).

Baselines will vary depending on the type of forest and land-use history. For example, deforested land may be subject to a wide range of stresses, including recurrent fires, soil compaction, waterlogging, salinization, erosion, loss of soil nutrients, lack of beneficial root fungi and bacteria, seasonal drought, low availability of seeds or rootstock, lack of suitable microhabitats for germinating seed and establishing seedlings, predation of seeds and seedlings, and severe competition with grasses or ferns (Florentine and Westbrooke 2004; Parrotta, Francis, and Knowles 2002).

Because all these processes affect tree growth, countries and landholders must consider them in developing

FIGURE 3. REDD+ Carbon Accounting: Reducing Emissions and Increasing Sequestration beyond Business as Usual



For both strategies, the difference between the baseline (dashed line) and the actual level achieved (solid line) is the amount that should be eligible for crediting and compensation.

baseline rates of carbon sequestration. That is, they must consider both stress conditions and forest type to determine a range of expected growth rates under business as usual. If landholders then improve forest growth rates above the baseline, they would receive payments for boosting carbon sequestration rates.

Carbon measurements in forests are done for both carbon storage and carbon flux. Carbon storage is the total metric tons of carbon per hectare. Carbon flux is the movement of carbon into or out of an ecosystem through either emissions or sequestration, measured as yearly metric tons of carbon per hectare.

Some changes in carbon sequestration rates will occur naturally as forests age (Figure 2). As they age, forests accumulate more tons of carbon, but the yearly rate of flux drops. Young and middle-aged forests therefore have higher rates of sequestration per year than older forests—although recent evidence shows that trees continue to grow, and therefore store small amounts of carbon, much longer than previously believed (Luyssaert et al. 2008; Pregitzer and Euskirchen 2004). Foresters must incorporate these changes into their baselines, and more studies on carbon storage and yearly flux in the tropics would be helpful (Pregitzer and Euskirchen 2004).

Although younger trees grow more quickly than older trees, cutting an older forest creates more carbon emissions than a young forest can sequester in any economically feasible time period. Cutting older forests to replant them therefore causes net emissions, and does not contribute to the overall goal of increasing sequestration (Liao et al. 2010).

National baselines that capture changes in forest emissions and sequestration are essential. Such baselines will enable nations to receive payments for mitigating climate change through a variety of forest-related activities across large areas. That is, some forest activities can produce carbon dioxide emissions as long as other activities sequester more.

National-level accounting also builds broad capacity to monitor forest emissions, promotes a transparent system (Verchot et al. 2010), and takes into account emissions that move from one location to another. In that phenomenon, known as "leakage," overall emissions from forests do not drop overall (Murray, McCarl, and Lee 2004).

Monitoring tropical forests in Honduras. Both remote sensing and on-the-ground monitoring are necessary to understand forest carbon flux.

CHAPTER 6

The Potential of Tropical Forests to Sequester Carbon

Some 2.3 million hectares of tropical forest are degraded every year (Wright 2005). The International Tropical Timber Organization (2002) estimates that degraded tropical forests now total some 850 million hectares, including 270 million hectares in Asia, 335 million hectares in South America, and 245 million hectares in Africa. Restoring more than 200 million of these hectares should be relatively easy, according to the Global Partnership on Forest Landscape Restoration (2009).

If countries could reforest 3.4 million hectares each year across the tropics, a REDD+ system could value those efforts at about $2.2 billion over 10 years. This would be in addition to the $2.9 billion nations could be paid for protecting existing tropical forests under a REDD+ system (Niles et al. 2002).

The Intergovernmental Panel on Climate Change reports that putting a price on carbon, such as under a REDD+ system, could spur tropical nations to sequester one metric gigaton of carbon per year through reforestation (Nabuurs et al. 2007). RIL practices in tropical areas now devoted to logging could retain around 0.16 metric gigaton of carbon per year (Putz et al. 2008).

Few on-the-ground studies have investigated the potential of tropical forest carbon sequestration. However, two studies did show that efforts to control competition increased carbon sequestration rates in tropical forests by 0.03 to 0.7 metric ton per hectare per year (Table 3) (Wadsworth and Zweede 2006; Winjum, Dixon, and Schroeder 1992).

The use of agroforestry practices across the humid tropics could sequester 1.5 to 3.5 metric tons of carbon per hectare each year (see Box 2, p. 16) (Montagnini and Nair 2004; Schroeder 1993), and reforestation could store about 1.3 metric tons of carbon per hectare per year (Winjum, Dixon, and Schroeder 1992). Modeling has shown that extending long timber-cutting

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Collecting soil samples in Nicaragua. Developing a baseline of current carbon levels in the forest and the soil is necessary to understand how these levels change with management.

TABLE 3. Increases in Carbon Sequestration in Tropical Forests from Various Activities

Forestry Activity	Estimated Metric Tons of Carbon per Hectare per Year
Thinning and weed control[1]	0.7
Managing land to reduce competition among species[2]	0.03
Agroforestry[3]	1.5
Reforestation[1,4]	0.5

Sources:

1 Winjum, Dixon, and Schroeder 1992.

2 Wadsworth and Zweede 2006.

3 Montagnini and Nair 2004; Schroeder 1993.

4 Niles et al. 2002.

Note: For values published as "tonnes of C per hectare over the course of a rotation," a 50-year rotation was used to determine annual rates.

rotations from 120 to 150 years can raise average carbon stocks in those stands by 12 percent (Kaul, Mohren, and Dadhwal 2010).

However, the most cost-efficient options will vary with each site (Hooper, Legendre, and Condit 2005). As noted, for example, analyses of the financial implications of RIL versus conventional logging have shown mixed results (Putz et al. 2008). A REDD+ system that pays countries for reducing emissions from tropical forests and boosting their growth rates beyond business as usual can shift this calculation and make RIL more profitable in more locations.

BOX 2.

The Multiple Benefits of Agroforestry

Agroforestry is the practice of growing traditional crops and a mix of trees on the same plot. Crop production is usually the main goal, so farmers typically plant a few widely spaced trees, to reduce interference with agriculture. The most famous example of agroforesty is the planting of cacao or coffee under shade trees (e.g., Duguma, Gockowski, and Bakala 2008; Beer et al. 1998).

These mixed-use, multi-species systems provide a variety of benefits. Thinning of the trees produces fuelwood for use or sale, and provides timber for crating other products such as fruit and nuts. Trees planted on pastures provide shade for livestock and can produce income when farmers sell the timber at the end of the rotation. The root systems of trees can also move carbon deep into the soil.

Agroforestry practices coupled with low-intensity farming can enable soil to sequester carbon. In the tropics, farmers can use such practices to sequester 1.5 to 3.5 metric tons of carbon per hectare per year (Table 3) (Montagnini and Nair 2004; Schroeder 1993). While farmers must consider heat-trapping emissions from the entire production system—cows in a pasture with trees release methane gas, for example—agroforestry practices can sequester carbon at higher rates than traditional agriculture while improving soil fertility. Such practices can also increase carbon storage on degraded lands.

Landholders can also rely on agroforestry as an intermediate step toward complete reforestation (Vieira, Holl, and Peneireiro 2009). This approach combines the economic benefits of short-rotation crops with a long-term investment in tree planting.

Landholders throughout the tropics can practice many types of agroforestry to sustainably produce both crops and carbon benefits. However, up-front costs may prevent these practices from being economically viable on a small scale, and for lower-value crops (Torres et al. 2010). National and international programs that reimburse the initial costs of agroforestry may spur more small landholders to practice it.

Shade-grown coffee in Mexico is an example of an agroforestry system in which an agricultural product and trees are grown in the same location, and benefits are garnered from both.

CHAPTER 7

Ensuring the Environmental and Social Integrity of REDD+

Environmental Safeguards

REDD+ activities should provide environmental benefits beyond reducing carbon dioxide levels in the atmosphere (Sedjo, Sampson, and Wisniewski 1997). Accounting for changes in carbon emissions and sequestration alone will not ensure the environmental integrity of these activities.

One such benefit is biodiversity, which is critical for safe and healthy human lives as well as ecosystem function (Millennium Ecosystem Assessment 2005). Biodiversity will be essential to enabling both people and ecosystems to adapt to the unavoidable consequences of climate change.

The role of secondary and plantation forests in providing habitat for diverse species has sparked significant debate (e.g., Brockerhoff et al. 2008; Chazdon 2008). Some of these forests provide important habitat while others do not. However, scientists have developed checklists for determining how beneficial various reforestation efforts can be in ensuring biodiversity (Brockerhoff et al. 2008). A REDD+ system should prioritize those that enhance biodiversity. For example, such a system should not encourage countries to establish forests in undisturbed areas that are naturally unforested, such as the savannah-like ecosystems of the Brazilian *cerrado*, as doing so can undermine existing species and the availability of water (Malmer et al. 2010).

Foresters can promote biodiversity by considering the type and number of species they plant, as those species influence the availability of food for wildlife and the ecosystem's resilience in the face of disturbances. Foresters can also consider the type and degree of site preparation, as that can affect competition from understory vegetation (Brockerhoff et al. 2008). Native species are essential to promoting biodiversity and ecosystem benefits, and a REDD+ approach should require the use of such species.

A young Honduran prepares to plant a mango tree.

Intensive monoculture tree plantations will often fail to support biodiversity (Spies 1997). However, managers can improve wildlife habitat even on timber-producing monoculture plantations. Silvicultural activities such as retaining individual trees or forest patches during harvest, actively propagating key species, and lengthening harvest rotations can help foster a more complex local ecosystem that supports some wildlife (Spies 1997). Still, a REDD+ mechanism should not finance activities on monoculture timber production plantations (of which there are few in the tropics).

Some techniques also reduce the negative effects of harvesting on biodiversity. For example, RIL can support biodiversity of animals and birds (Imai et al. 2009; Felton et al. 2008; Wunderle, Henriques, and Willig 2006). Retention harvesting, in which foresters leave standing trees, snags, coarse woody debris, and organic

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soil layers on-site, creates complex habitat niches. These complex stands are a useful approach to managing forests for multiple objectives, such as producing both wood products and some ecosystem services (Franklin et al. 1997).

Finally, sound carbon accounting is an important tool for safeguarding the environment. To properly implement carbon accounting, policy makers will need to agree on an environmentally sound definition of tropical forests. While forests vary from country to country, such a definition should value ecosystem services and reduce perverse incentives.

For example, recent studies show that cutting a natural forest and shifting to a plantation forest decreases the amount of carbon sequestered on-site, and thus is not a viable REDD+ tool (Liao et al. 2010). A REDD+ system should provide financial incentives only for planting trees on land that is already degraded or abandoned, to discourage such high-emissions activities.

Social Safeguards

A REDD+ mechanism must also include social safeguards for forest-dependent peoples. About 800 million inhabitants in rural and indigenous communities live in or near tropical forests. Many of these residents rely on local forests for their livelihoods, and have accumulated important knowledge on how to manage them (Chomitz et al. 2007; Berkes, Colding, and Folke 2000). REDD+ policies must require the full consent and participation of indigenous peoples and local communities, and ensure that they share in the financial benefits equitably. By including appropriate safeguards, REDD+ can help secure the rights and sustainable development of indigenous peoples and forest communities.

Many international instruments codify these rights. These include the International Labor Organization's Convention Concerning Indigenous and Tribal Peoples in Independent Countries; the United Nations Declaration on the Rights of Indigenous Peoples; the Universal Declaration of Human Rights; the UN Declaration on the Right to Development; the International Covenant on Economic, Social, and Cultural Rights; and the International Covenant on Civil and Political Rights.

National governments have recently been devolving ownership of and access to land to local communities and indigenous peoples (Sunderlin, Hatcher, and Liddle 2008; White and Martin 2002). For example, the Rights and Resources Initiative and the International Tropical Timber Organization recently examined 30 countries that are home to 85 percent of tropical

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An indigenous community in the Amazon region of Ecuador.

forests worldwide. The researchers found that the amount of forested land administered by governments shrank by 15 percent from 2002 to 2008, while the amount owned by communities and indigenous peoples grew by 22 percent (RRI and ITTO 2009). The amount of forested land set aside for use by communities and indigenous peoples also expanded by 66 percent.

However, much of the significant change occurred in a few countries such as Brazil. And the rate of change in forest tenure in Amazonia far exceeded that in the Congo Basin, the second-largest tropical forest region. The forces behind the global trend include movements by indigenous peoples to claim their lands, democratic decentralization of government, and an alignment among conservation groups, development organizations, and local communities (Larson, Barry, and Dahal 2010).

Ensuring land ownership rights and participation of local forest communities is an effective way to maintain carbon stocks in forests, and will help create a functioning and effective REDD+ mechanism. For example, in the Brazilian Amazon, the probability of deforestation has been 7 to 11 times lower on indigenous lands and protected areas than in other regions since 2002 (Ricketts et al. 2010).

One study of 80 forest commons across 10 countries found that those with a high degree of local autonomy in forest management were more likely to have above-average carbon storage, and produce greater benefits to local livelihood (Chhatre and Agrawal 2010). Communities with secure rights to forest tenure are also more likely to conserve carbon. A study in Mexico found that community forestry reduced deforestation and encouraged reforestation more effectively than simply protecting land (Ellis and Porter-Bolland 2008). Such forests provide income to local residents while simultaneously requiring adherence to national environmental laws, thereby promoting both ecological sustainability and local development (Bray, Antinori, and Torres-Rojo 2006; Bray et al. 2003).

A REDD+ mechanism should not only recognize the rights of indigenous peoples and local communities to the lands and resources they have occupied or owned, as the United Nations Declaration on the Rights of Indigenous Peoples specifies. Such a system should also ensure the full and effective participation of such peoples and communities in creating and implementing it. REDD+ policies should also fully support the sustainable development of indigenous peoples and local communities, and recognize and incorporate traditional knowledge and practices.

CHAPTER 8

Policy Recommendations

A comprehensive REDD+ framework should aim primarily to stop the deforestation and degradation of tropical forests, but also to increase carbon sequestration rates on already degraded and managed lands. Such a framework can rely on policies at multiple levels.

International Policies

International REDD+ policies that place economic value on the carbon already stored in tropical forests, and on the carbon they could sequester, are essential to mitigating climate change. As markets adjust, tropical forests will no longer be seen as a marginal product that can be exploited while production forests catch up to demand for wood products (Clapp 2001).

The REDD+ agreement that negotiators are now developing under the UN Framework Convention on Climate Change (UNFCCC) is an important multilateral tool, and it does include social and environmental safeguards. However, negotiators have not yet agreed on how participating countries will develop baselines and show that their carbon benefits are additional. International REDD+ policies should require participating countries to show how carbon emissions dropped and sequestration rose beyond business as usual.

The UNFCCC process is likely to encourage the broadest participation among nations worldwide, which will be critical to achieving the full potential of REDD+ to mitigate climate change. The UNFCCC should aim to reduce carbon emissions from deforestation and degradation of tropical forests 50 percent by 2020, and to reduce emissions to net zero by 2030. Nearly eliminating tropical deforestation and degradation would provide the majority of emissions

IPCC Chairman Rajendra Pachauri speaks to negotiators at the 15th Conference of the UNFCCC Parties in 2009.

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cuts needed to reach that goal, with sequestration offsetting any remaining emissions. To achieve the 2030 goal, sequestration activities must begin in the next few years (Figure 4).

A REDD+ system should encourage developing countries to pursue all appropriate REDD+ activities, even if not simultaneously. For example, a country may be fully prepared to claim cuts in emissions through avoided deforestation, but it may not yet have established forests for increased sequestration. Ultimately, increased payments will incentivize countries to move forward in each REDD+ activity. A multilateral system can help countries share information and experiences on all aspects of REDD+.

Some developing countries are already working on the full range of REDD+ activities, while others need to develop the capacity to participate in some of them. International recognition of progress can spur developing countries to move from building the capacity to measure baselines (early phase) to pursuing forest management activities financed by carbon markets (final phase).

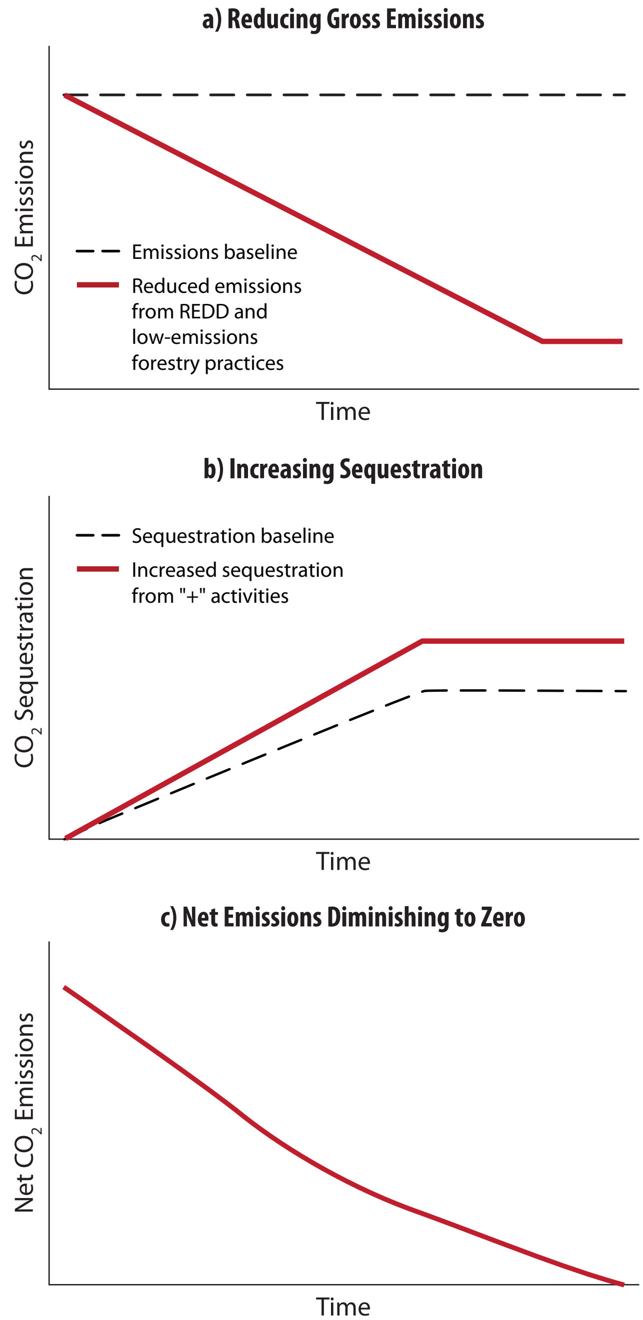
National Policies

National-level planning is critical to ensuring that developing countries with tropical forests work comprehensively to mitigate climate change. A comprehensive approach can help nations implement the vast array of opportunities to manage forests at a variety of scales (Birdsey, Pregitzer, and Lucier 2006).

National policies that spur all appropriate REDD+ activities will capture the full range of dynamics that influence forest carbon emissions and sequestration, and thus enable those nations to achieve zero net emissions (Harmon 2001). National policies should include explicit targets for reducing carbon emissions from tropical forests and increasing sequestration. National-level accounting and monitoring of global warming emissions from forests can also help ensure that carbon sequestration is permanent, protect against leakage, and verify that emissions reductions and sequestration increases are additional—that is, above business as usual.

Today many national plans and policies ignore the potential to reduce carbon emissions from degraded land, and to increase sequestration through reforestation and restoration (International Tropical Timber Organization 2002). That may change given that the first national programs to compensate landowners for reforestation and restoration have been deemed successful (Daniels et al. 2010).

FIGURE 4. Theoretical REDD+ Carbon Accounting to Reach Zero Net Emissions by 2030



Reducing emissions will comprise most of the effort (a); increasing sequestration (b) will make it possible to reach zero net emissions (c).

Carbon sequestration is not the primary goal of most forest managers, and nations need to create economic incentives to spur them to shift to practices that reduce emissions and store carbon. Such incentives could include payment for ecosystem services (PES) programs,

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Measuring trees in Nicaragua—an important piece of a comprehensive program for monitoring forest carbon.

tax breaks, contracts, subsidies, and carbon markets (Richards et al. 1997).

Governments can also create institutional incentives, such as clarification of private and collective property rights, market reforms, community forestry, education and extension services, research and development, and volunteerism (Richards et al. 1997). Mexico provides a powerful example of how national laws and frameworks—including subsidies and training—can support community forests. These areas provide income that remains in the local community, while simultaneously being held to national environmental laws (Bray, Antinori, and Torres-Rojo 2006; Bray et al. 2003). Thus, Mexican community forestry provides an example of how governance decisions can promote both ecological sustainability and local development.

A variety of national and local policies and incentives can encourage locally appropriate practices that reduce carbon emissions, increase sequestration, and safeguard forests. These include royalties and performance-based bonds for loggers and land owners who pursue sound forest management, and performance-based renewal of land tenure (Boscolo and Vincent 1998). These provisions will require monitoring and enforcement.

Carbon sequestration is not the primary goal of most forest managers, and nations need to create economic incentives to spur them to shift to practices that reduce emissions and store carbon.

Demand for forest and agricultural products is global, so forest policies in individual countries can have a profound impact on the supply of a product, and ultimately alter the forest industry in another country. For example, unrelated policies of four key suppliers of hardwood chips to Japan—Australia, Indonesia, Malaysia, and New Zealand—reduced the regional supply of such chips in the 1980s. Japan then turned to Chile, where no policies prevented the use of native tropical hardwood forests for wood chips, and poor enforcement of forest policies on sustainability that did exist allowed lapses (Clapp 2001).

REDD+ policies in developed countries are also essential, as demand for timber, soybeans, beef, and palm oil in the United States, Japan, and the European Union drives the destruction of tropical forests (Boucher 2010). The 2008 amendments to the U.S. Lacey Act are the only trade ban on illegally logged timber (Environmental Investigation Agency 2007), although the European Commission's action plan for Forest Law Enforcement, Governance and Trade also promotes sustainable forest management.

To ensure forest management activities ultimately lead to climate change mitigation, countries must set appropriate baselines and only receive incentives for activities that go beyond business as usual and which meet social and environmental safeguards. Local, national, and international policies can be developed to promote and provide positive incentives for all REDD+ action.

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The Plus Side

Promoting Sustainable Carbon Sequestration in Tropical Forests

Deforestation and forest degradation in tropical countries account for about 15 percent of total global warming pollution. A set of policies known as REDD+ aims to reduce heat-trapping carbon dioxide emissions from tropical deforestation and degradation (REDD), and to increase carbon sequestration in tropical forests (the "plus") by conserving existing forests, restoring degraded forests, seeding new forests, and managing them in a sustainable fashion.

This report explains how a variety of forestry practices can be used to achieve "the plus side" of REDD+ policies, while meeting strict standards for protecting the environment and local cultures. If applied effectively, the full range of REDD+ activities can turn forests from a source of carbon dioxide emissions into a sink.

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